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MATTERS RELATING TO LIFE SCIENCES, INCLUDING SPACE MEDICINE

Space biology and medicine and their contribution to solving human health problems: results and prospects

Working Paper submitted by the Russian Federation

Beginning with the flight of Yuri Gagarin, the duration of space flights has gradually increased and the amount of work carried out in outer space has grown. If one were to evaluate the past 30 years of the study of man in space, three fundamental results should be underscored:

- The basic physiological effects of weightlessness and the systems most adversely affected by it have been identified;
- The stages in which the human body adapts to weightlessness have been defined;
- A system for providing medical protection during space flights has been devised.

The research conducted on a wide range of biological objects during flights of the Cosmos-series manned stations and biosatellites has made a major contribution to the study of many medical and biological problems.

In the field of gravitational biology, basic research was designed to study the role of weightlessness as an ecological factor and determine the nature of its effect on various forms of organization of life. This research provided unique material for working out the problem of the evolutionary role of the Earth's gravity.

It has been established that weightlessness does not cause gene or chromosome mutations and, as a rule, does not impair the cell-fission mechanism. At the same time, the possibility that certain physiological reactions by an organism to lack of gravity may result from modified cell behaviour has not been discounted. In future, it will be necessary to determine to what extent the effect of weightlessness depends on the type of cell differentiation and the degree of functional load. The role of the genetic apparatus in mechanisms by which an organism adapts to prolonged weightlessness should be studied in greater detail. In general, we may assume that lack of gravity does not prevent the occurrence of the basic stages in the life cycle of an organism.

By improving the experimental basis for space research and developing the necessary instruments, it was possible to conduct the Svet and Inkubator experiments on the Mir orbital station. The experiment with the Svet greenhouse (the only space-flight greenhouse in the world), in which environmental conditions were created that were fully compatible with the needs of vegetable organisms, succeeded for the first time in demonstrating that lack of gravity does not impede form-building processes or the outflow of plastic substances from leaves. As a result of this, radish roots were grown for the first time in conditions of weightlessness. Nevertheless, the questions relating to plant productivity, which proved to be lower in weightlessness conditions than on Earth, and also reproduction processes remain unresolved.

The Inkubator-2 experiment was the first experiment in the world which demonstrated that the embryonic development processes of birds could occur normally under conditions of weightlessness. Normally developed, viable chicks with active motor, feeding and vocal behaviour were hatched for the first time in weightlessness conditions, which shows that weightlessness has no direct harmful effect on the processes of embryogenesis.

In the field of space radiobiology, considerable attention has been given to research into the mechanisms of the effect of the heavy component of galactic space rays. For instance, it was demonstrated that high-energy particles cause specific damage to nuclear cell-structures. The data obtained were used to develop new concepts concerning radiation risk in order to improve the radiation security system for astronauts, which can also be utilized in interplanetary travel.

Making use of the potential of space flight and its achievements to protect health and provide medical treatment on Earth is a kind of connecting link between results and prospects and the past and the future. Work is being conducted here in a number of areas.

One such area is the transmission of various types of medical information over great distances. In order to ensure medical monitoring of the physical condition of astronauts, special methods and corresponding instruments have been developed, which make it possible to record and transmit to Earth by means of telemetry various physiological and biochemical parameters indicating

the condition of all bodily systems. This enables doctors to acquaint themselves very fully with the health of cosmonauts orbiting hundreds of miles away in outer space. The principles of this kind of remote diagnostics or "telemedicine" may be successfully used very widely on Earth. Some experience has already been acquired in the linking by satellite of hospitals, medical institutions and doctors in remote areas or on ships at sea with leading medical centres in order to transmit the information needed to carry out a diagnosis or a skilled consultation. A vivid example of the possibilities of telemedicine may be seen in the results of the "telemedical bridge" organized at the initiative of the United States National Aeronautic and Space Administration (NASA) and a number of Soviet organizations for the purpose of providing medical assistance to the victims of the earthquake in Armenia. Via a system of satellites, a "tele-bridge" was organized between the Republican Diagnostic Centre in Yerevan and four medical centres in the United States. In order to conduct consultations, use was made of voice, video and facsimile communications. More than 30 conferences were held and over 200 patients were consulted; in all, teleconferencing influenced the diagnosis and treatment of no less than 2,000 victims of the earthquake. The tele-bridge demonstrated the extremely effective nature of such a system in providing medical assistance to victims of natural disasters and highlighted the prospects for using such systems in solving many problems relating to human health care.

Another aspect of the application of the achievements of space exploration in terrestrial medicine is the use of the methodology and apparatus devised for the selection and training of cosmonauts and for the conduct of medical research in outer space. Nowadays growing use is made in terrestrial clinics of equipment on which it would be fully justified to write "made for outer space". They are distinguishable by their compactness, simplicity of operation and high reliability.

The apparatus bearing the name Argument has gained a good reputation for its use in outer space in the ultrasonic monitoring of the heart and major vessels. With its aid it is possible to examine the heart and to ascertain - from inside, as it were - the condition of its cavities and arteries and the operation of its valves and muscle. This portable apparatus is already being used successfully in ambulances, thereby greatly expanding the possibilities for emergency diagnosis of cardiovascular illnesses.

The Tonus equipment used in space medicine for muscular electrostimulation is applied in traumatological practice for strengthening the muscular system in the case of postural problems, platypodia, muscular atrophy, and also during the post-operative period to avert thrombogenesis.

The electrochemical water-quality analyser is used for hygienic and epidemiological monitoring of the purity of drinking water, groundwater and waste water. This instrument makes it possible to determine the presence of trace quantities of heavy metals and organic impurities in liquid media. It enables water to be analysed both under field conditions and in automatic monitoring systems.

The methodology used in outer-space research on the cardiovascular system can be successfully applied in the diagnosis and treatment of cardiovascular illnesses on Earth. This is because during space flight less significant changes in blood circulation are observed than in the case of sick persons. It was therefore necessary to devise a number of new techniques and instruments for analysing masses of information in order to diagnose and monitor comparatively small functional changes at the earliest stage. Use of this methodology for discerning initial functional changes opens up the possibility of forecasting harmful changes and of applying treatment in good time.

A space technique of assessing the functioning of the otological apparatus is applied in the clinical practice of otorhinolaryngology and otoneuralgia and in the professional monitoring of sportsmen and those engaged in the aeronautical professions.

The methodology used in space medicine for the psychological selection and training of persons for work under extreme conditions and for the selection of groups on the basis of psychological compatibility is being increasingly applied in terrestrial practice.

The methods and simulators devised to counter the adverse effects of prolonged weightlessness on cosmonauts are being applied in sports medicine and in the rehabilitation of sick persons.

Lastly, the study of human beings in outer space under conditions of weightlessness has greatly expanded and deepened our knowledge of human health. It may be stated that space exploration itself has enhanced "terrestrial" doctors' understanding of the mechanisms of human spatial orientation, of the vestibular apparatus and its structure and functions, and their knowledge of biomechanics, metabolism and the cardiovascular and central nervous systems.

That, in the broadest terms, is the picture of the "outer-space contribution" to the solution of problems involving human health care. Despite the already discernible results of its introduction in health-care practice, space medicine is still indebted to terrestrial medicine: the latter's experience has been utilized more than has been acknowledged. That is understandable: basically only the first steps have been taken in this direction.

Today there is very high awareness of and interest in the application of the achievements of space exploration and space medicine to health care. It is no coincidence that the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82), in one of its main recommendations, noted that all countries should have the opportunity to use the methods devised as a result of medical research in outer space. That is why it is not the first year that this question appears on the agenda of the Scientific and Technical Subcommittee of the Outer Space Committee.

As to the prospects for the development of space physiology and biology, future research may, in the most general sense, take the following directions:

- Detailed study of the causes and processes involved in the changes in basic physiological functions of the human body, differentiating the specific changes due to the physiological nature of weightlessness from the adaptive reactions of the body to that phenomenon;
- Further elaboration and modernization of ways and means of treating dysfunctions due to the effects of flight;
- Further elaboration of the theory, methods and implementation of the planned control of the state of health and work capability of the members of crews in flight;
- The calculated use of weightlessness to study general biological problems due to the effects of gravitation on living systems.

Soviet scientists specializing in space biology and medicine consider that the solution of basic problems in the aforementioned research areas will make it possible to carry out a number of projects:

(a) Creation of a specialized medical and biological laboratory (Medilab) as part of a future orbital complex. As the technical basis for the project, a number of alternate designs have been put forward for a medical centre equipped with the most up-to-date diagnostic, measuring, experimental and computer apparatus, which would be part of a new generation of orbital station. Physicians, physiologists and biologists working in the medical and biological laboratory would carry out a broad range of basic and applied in-flight research.

(b) Development of a new generation of biosatellites with a longer operational life. By 1995, the operational life of such satellites could be increased to 30 days and, by the year 2000, to 120-180 days. Moreover, opportunities for conducting various types of experiments will increase substantially. Outlays for such research would be recovered by the acquisition of new basic knowledge necessary for predicting reactions to the prolonged effects of space flight. Research conducted on biosatellites can also be used to develop and test elements of the life-support system.

(c) The Mars project. A number of medical and biological problems must be solved before a manned expedition to Mars can be carried out. One such problem is that of habitability, which must be solved through the development of a biologically complete and ecologically sound living environment capable of meeting the long-term biological needs of human beings. This question requires thorough scientific study. Existing life-support systems must be replaced by a complete living environment modelled on the Earth's biosphere. It will be necessary to create on board the spacecraft to Mars a model of the natural ecological system, whose active constituents will be human beings, animals, plants and micro-organisms. The development of such a model analog

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must include regenerative systems for life support with a high coefficient of recycling.

In spite of the existing differences in the assessment of radiation levels, in general, specialists agree that, given the current degree of sophistication of technical equipment and methodologies, there is reason to hope that ways of guaranteeing the radiation safety of an expedition to Mars will be found.

The solution of psychological problems, and the psychological preparedness of human beings to undertake a flight that inevitably involves a certain degree of risk, are other important aspects of preparations for a Mars expedition.

The manned flight to Mars will also require the solution of a number of physiological problems related to a prolonged state of weightlessness (artificial gravity, on-board centrifuge).

The effective implementation of the aforementioned projects, as well as the further development of space flight as a whole, will undoubtedly benefit from the concerted efforts of many countries. On the whole, international cooperation in the field of space biology and medicine has yielded good results. Together with the scientists from different countries, our specialists are conducting diverse experiments on Earth and in outer space, and are developing research methods and equipment. For example, biochemical research has been carried out on Soviet orbital stations using the Czechoslovak Plasma and Reflotron devices (Berringer-Mannheim Company), the French Echograph apparatus for the ultrasonic study of internal organs, and the Polish Physiostest apparatus for functional tests with physical loads.

Today the international community must concentrate its efforts on priority areas in the exploration and use of outer space, and should avoid duplication and the unwarranted dissipation of resources and efforts. Experience shows that the participation of various countries in research and experiments conducted in outer space itself increases interest in space travel and stimulates the participation of those countries' industrial and scientific research organizations in space activities, which also directly benefits the national economy. Moreover, the equipment and methods developed for outer space research can subsequently be used successfully on Earth.

The process of uniting the efforts of mankind in the peaceful use of outer space is gaining momentum. The important thing is that everything done in that area should be done for the welfare and health of human beings both in outer space and on Earth.

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